Aran, Galway Bay and Slyne Head *Nephrops* Grounds (FU17) 2013 UWTV Survey Report and catch options for 2014.

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Abstract

This report provides the main results and findings of the twelfth annual underwater television on the Aran, Galway Bay and Slyne head *Nephrops* grounds, ICES assessment area;

Functional Unit 17. The survey was multi-disciplinary in nature collecting UWTV, fishing, CTD and other ecosystem data. In total 31 UWTV stations were successfully completed in a randomised isometric grid design at 3.5nmi or 6.5km intervals over the known range of the stock on the Aran Grounds. The mean burrow density observed in 2013, adjusted for edge effect, was 0.32 burrows/m². The final krigged burrow abundance estimate was 317 million burrows with a CV (or relative standard error) of 4 %. Abundance estimates have fluctuated considerably over the time series. The abundance decreased significantly in 2012 and the 2013 estimate was 2% lower and the lowest estimate in the 12 year time series. Raised abundance estimates for Galway Bay and Slyne Head were also low for those areas. Using the 2013 abundance estimate together with updated parameters for mean weight and proportions of removals retained implies 2014 total catch advice fishing at F_{msy} ($=F_{35\%spr}$) of 699 tonnes which results in landings of no more than 591 tonnes. *Nephrops* accounted for approximately 70% of the benthic catch by weight from 7 beam trawl tows. The observed length frequency and maturity of female *Nephops* caught was similar to previous years. *Virgilaria mirabilis* was the most common of the two sea-pen species observed on the UWTV footage (*Pennatula phosphorea* was also present).

Key words: *Nephrops norvegicus*, stock assessment, geostatistics, underwater television (UWTV), benthos.

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Introduction

The prawn (*Nephrops norvegicus*) are common around the Irish coast occurring in geographically distinct sandy/muddy areas where the sediment is suitable for them to construct their burrows. The *Nephrops* fishery in VII is extremely valuable with landings in 2012 worth around € 80 m at first sale. The *Nephrops* fishery 'at the back of the Aran Islands' can be considered the mainstay of the Ros a Mhíl fleet. Reported landings in 2012 were worth and estimated €5.5 m at first sale. Without this *Nephrops* fishery the majority of vessels in the fleet would cease being economically viable (Meredith, 1999). Given these socio-economic realities good scientific information on stock status and exploitation rates are required to inform sustainable management of this resource.

Nephrops spend a great deal of time in their burrows and their emergence behaviour is influenced by several factors: time of year, light intensity, tidal strength, etc. Underwater television surveys and assessment methodologies have been developed to provide a fishery independent estimate of stock size, exploitation status and catch advice (ICES, 2009a & 2012a). This is the twelfth annual UWTV survey of the 'Aran grounds'. The survey covers three geographically discrete mud patches; the Aran Ground, Galway Bay and Slyne Head all of which lie within the ICES assessment area Functional Unit 17 (FU17) (Figure 1). The 2013 survey was multi disciplinary in nature; the specific objectives are listed below:

1. To complete randomised fixed isometric survey grid of 31 UWTV with 3.5 nautical mile (Nmi) spacing stations on the "Aran" *Nephrops* ground.
2. To carry out >5 UWTV indicator stations on the Galway Bay and Slyne Head *Nephrops* ground.
3. To obtain 2013 quality assured estimates of *Nephrops* burrow distribution and abundance on the "Aran" *Nephrops* ground (FU17). These will be compared with those collected previously.
4. To collect ancillary information from the UWTV footage collected at each station such as the occurrence of sea-pens, other macro benthos and fish species and trawl marks on the sea bed.
5. To collect oceanographic data using a sledge mounted CTD.
6. To sample *Nephrops* and macro benthos using a 4 m beam trawl deployed at ~10 stations.
7. To use the time saved (from reduced grid in FU17 Aran Grounds) to extend the UWTV survey to FU16 Porcupine.

This report details the final UWTV results of the 2013 survey and also documents other data collected during the survey. The 2013 abundance are used to generate catch options for 2014 in line with the recommendations and procedures outlined in the stock annex for FU17.

Material and methods

As in 2012 a randomised isometric grid of 31 stations every 3.5Nmi or 6.5km was used for 2013 survey to achieve good spatial coverage over the known extent of the ground and to generate burrow surface that reflects the underlying abundance. The same ground boundary has been used for the Aran grounds throughout the time series. Stations in Galway Bay and Slyne Head were randomly picked from an area defined by previously collected UWTV data, VMS data and multi-beam backscatter data (Figure 1 & 2). The boundary use to delineate the

edge of the ground was based on information from the fishing industry and has not been changed since 2002.

Survey timing was generally standardised to June each year. In 2003, poor weather and technical problems meant that coverage was poor compared with the other years. In 2004, bad weather prevented the completion of the survey in June so approximately 50% of the stations were carried out one month later in July. In 2003 and 2008 due to weather downtime stations could not be completed at Slyne Head. In 2013 all three *Nephrops* grounds were surveyed successfully during June 10^{th} -19^{th} on RV Celtic Voyager.

The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and employed on other UWTV surveys in Irish waters. These protocols can be summarised as follows: At each station the UWTV sledge was deployed. Once stable on the seabed a 10 minute tow was recorded onto DVD. Time referenced video footage was collected by one video camera with a field of view or 'FOV' of 75 cm. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 1 to 2 seconds. The navigational data was quality controlled using an "r" script developed by the Marine Institute (ICES, 2009b) an example is shown in Figure 3. In 2013 the USBL navigational data was used to calculate distance over ground for 99% of stations whereas ship data was used for the remaining 1% of stations.

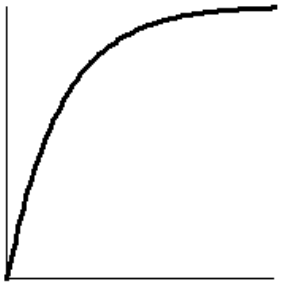
In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and validated using reference footage for the Aran Grounds prior to recounting at sea (ICES, 2009b). Figure 4 shows individual's counting performance in 2013 against the reference counts as measured by Linn's concordance correlation coefficient (CCC). A threshold of 0.5 was used to identify counters who needed further training. Once this process had been undertaken, all recounts were conducted by two trained "burrow identifying" scientists independent of each other on board the research vessel during the survey. During this review process the visibility, ground type and speed of the sledge during one-minute intervals were subjectively classified using a classification key. In addition the numbers of *Nephrops* burrows complexes (multiple burrows in close proximity which appear to be part of a single complex which are only counted once), *Nephrops* activity in and out of burrows were counted by each scientist for each one-minute interval was recorded. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009b).

Notes were also recorded each minute on the occurrence of trawl marks, fish species and other species. Abundance categories of sea-pen species were also recorded due to OSPAR Special Request (ICES 2011). A key was devised to categorise the densities of seapens based on SACFOR abundance scale (Table 1) after ICES (2011). Finally, if there was any time during the one-minute where counting was not possible, due to sediment clouds or other reasons, this was also estimated so that the time window could be removed from the distance over ground calculations. Consistency and bias between individual counters was examined using Figure 5. There is some variability between counters but no obvious bias or excessive deviations.

The recount data were screened for one minute intervals with any unusually large deviation between recounts. These minutes were re-verified by means of consensus counts. Means of the burrow and *Nephrops* recounts were standardised by dividing by the survey area observed. Either the USBL or estimated sledge lay-back were used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated at 75cm

assuming that the sledge was flat on the seabed (i.e. no sinking). This field of view was confirmed for the majority of tows using lasers during the 2013 survey. Occasionally the lasers were not visible at the bottom of the screen due to sinking in very soft mud (the impact of this is a minor under estimate of densities at stations where this occurred).

To account for the spatial co-variance and other spatial structuring a geo-statistical analysis of the mean and variance was carried out using SURFER Version 10.7.972. The spatial structure of the density data were studied through variograms. The mid-points of each UWTV transect were converted to the Universal Transverse Mercator geographic coordinate system (UTM). In 2013 there was no need to include addition stations, with assumed zero density outside the known distribution of *Nephrops* or suitable sediment, in the krigging process. An un-weighed and un-smoothed omni-directional variogram was constructed with a lag width of approximately 1000m and maximum lag distance of between 17-20 km. A model variogram $\gamma(h)$ was produced with an exponential model (see below). Model fitting was via the SURFER algorithm using the variogram estimation option. Various other experimental variograms and model setting were examined before the final model choice was made.



Exponential Model
Cressie (1991, p. 61)

$$\gamma(h) = C\left[1 - e^{-A}\right]$$

The resulting annual variograms were used to create krigged grid files. Then surface plots of the grids were made using a standardised scale. The final part of the process was to limit the calculation to the known extent of the ground using a boundary blanking file. The resulting blanked grid was used to estimate the domain area and total burrow abundance.

Although SURFER was used to estimate the burrow abundance this does not provide the krigged estimation variance or CV. This was carried out using the EVA: Estimation VAriance software (Petitgas and Lafont, 1997). The EVA burrow abundance estimates were all extremely close to the Surfer estimate (+- 55 million burrows) with the exception of 2004 when the spatial coverage was poor.

To estimate the abundance for Galway Bay and Slyne Head grounds, the area of each ground based on a VMS delimited polygon was calculated in ArcGIS10 and an average value used (Table 2). The abundance estimation is the product of the mean density and ground area. The sample variances, standard errors, t-values and 95% CI were calculated for each ground.

For each UWTV station a CTD profile was logged for the duration of each tow using a Seabird SBE37. This data will be processed later.

Seven valid beam trawl tows were conducted randomly across the Aran grounds once TV operations were successfully completed. All *Nephrops* caught were sorted by sex and maturity category, weighed and measured using the NEMESYS electronic measuring system.

A length stratified sub-sample of *Nephrops* was taken for each haul. Individual length, whole weight, tail weight, maturity. This year samples of males were frozen for measuring appendix masculina lengths back in the laboratory. These results will be available later. The fish catch was identified to species level sampled by weight (kgs) only. The benthic catch was identified weight (g) and counted. The UWTV station positions and tracks for the seven valid beam trawl tows are shown in Figure 1.

Results

The station positions are shown in Figure 2. Histograms of the observed burrow densities from 2002 to 2013 are presented in Figure 6. This shows relatively large inter-annual variation in modal burrow densities. The 2013 modal adjusted[1] density was between 0.4 – 0.45 burrow/m^2. It was very noticeable that there was a substantial reduction in density throughout the ground with only one density estimates > 0.7/m^2. Figure 7 and Figure 8 show the variability in density between minutes and operators (counters) for each station. These show that the burrow estimates are fairly consistent between minutes and counters.

The geostatistical structural analysis is shown in the form of variograms in Figure 9. There are a few outliers apparent but they appear to have little leverage on the variogram models observed. There is weak evidence of a sill at around 12km in some years but it is not clear and the exponential model used does not have a sill. The blanked krigged contour plot and posted point density data are shown in Figure 10. The krigged contours correspond very well to the observed data.

The results indicate the densities have fluctuated considerably over the time series and throughout the ground. The fluctuations are not limited to a single station but instead occur fairly homogeneously across the ground. In general the densities are higher towards the western side of the ground and there is a notable trend towards lower densities towards the east. On the south western boundary there are indications of high densities close to the boundary. In this area there is a sharp transition from mud to rocky substrate and work is underway to define this boundary more accurately (Figure 1). The decline in density throughout the area in 2012 and 2013 is striking. Densities in the middle and northern part of the ground are in general 50% lower than was observed in 2011.

The summary statistics from this geo-statistical analysis for the Aran Grounds are given in Table 3 and Figure 11. The 2013 adjusted estimate of 317 million burrows is a 2% lower than in 2012 (but that is not statistically significant). The estimation variance of the survey as calculated by EVA is relatively low (CVs in the order <6%). The 2013 adjusted abundance estimate is 56% below the geometric mean of the series (732 million burrows). The abundance estimates for the Aran Grounds have fluctuated considerably each year to date but there is a declining trend in recent years.

The summary statistics for the stations on Slyne head and in Galway Bay are given in Table 4. Data for years 2002 – 2008 have been revised but analyses show that there is no major change to the overall trend. Raised adjust abundance estimates for Galway Bay *Nephrops* ground and for Slyne Head *Nephrops* ground also are shown in Figure 11. The Galway Bay mean estimates fluctuate widely but appear to be highly correlated with the Aran ground (except

[1] Note the "adjusted" density estimates in this report are adjusted by dividing by 1.3 to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).

2004). Estimates for the Slyne Head ground also fluctuate considerably but show no significant correlation with the other areas. The uncertainty bounds for both areas also fluctuate and inter-annual changes are only statistically significant in a few years. On average the Aran Grounds account for ~89% of the total estimated burrow abundance from FU17. Galway Bay and Slyne Head account for 8.6% and 2.2% respectively.

Figure 12 show the standardised length frequency distributions (LFDs) by sex of *Nephrops* caught using a beam trawl on the Aran grounds between 2006 and 2013 surveys. No fishing was carried out on surveys prior to 2006 or in 2008 (due to time constraints as a result of poor weather conditions). For plotting purposes the individuals <10mm caught in 2010 were split evenly between males and females as it is not possible to accurately assign sex to individuals that small. There is weak indication of a year class signal in 2010 and 2011 but few individuals less than 20mm in most years. The mean lengths for both sexes in the survey have been fairly stable over time around the overall average of 27.61 mm. It should be noted that there is some variability between the sample sizes and structure for individual hauls shown in Figure 13. Carapace lengths in 2013 ranged from 17 mm to 43 mm for one large male and 13 mm to 44 mm for one large female.

In 2013 various morphometric measurements were made during the survey. The estimated length-weight parameters are given in Table 5 together with those currently used in data raising and by ICES for this stock. Bias correction factors for the length-weight conversions are also provided since linear models were fitted to the log CL and log weight data. Male growth was allometric and no significant difference was observed for the b parameter compared to that currently used for the stock. Female growth is isometric and the estimated b parameter was also not statistically different ($p>0.01$) than that used by ICES.

Figure 14 depicts a modelled maturity ogive (binomial GM) for female *Nephrops* where 50% of the females are mature at 23 CL mm. The 2013 results of the study of appendage masculina length (mm) will be presented at a later stage as processing will be undertaken ashore rather than at sea for this fine-scale study.

A summary of the benthic taxa by tow is presented in Table 6. *Lunatia species* (necklace shell) was the most abundant species and was recorded in all tows. *Goneplax rhomboids*, a burrowing crab species, was also caught in all of the tows. *Munida rugosa* (squat lobster) was recorded in one tow and this species makes shallow burrows which are often observed on the Porcupine Banks (FU16). *Eledone cirrhosa* (curled octopus) was also recorded in five tows, this species is a noted predator of crustaceans and has been filmed lying close to or at the *Nephrops* burrow entrances on the Smalls ground (FU22). Table 7 summarises the fish catches. *Glyptocephalus cynoglossus* (witch) was recorded in all beam tows with the highest catch of 0.632 kgs recorded in tow 7. *Merlangius_merlangus* (whiting) was also present in all tows and was the biggest catch recorded of 1.298 kgs in tow 6.

The sea-pen presence-absence observations across the *Nephrops* grounds are mapped in Figure 15 using the key described in Table 1. The majority of sea-pens were identified from the video footage as *Virgularia mirabilis* and there was one observation of *Pennatula phosphorea*. *V.mirabilis* was also present at stations where trawl marks were recorded. This seapen species was recorded as frequently present at 19% and occasionally present at 26% of total stations. Trawl marks were noted at 51% of the Aran stations surveyed with trawl marks present for the entire video transect for 25% of stations. Trawl marks were present at one video transect at both Galway Bay and Slyne Head.

Total catches and landings options at various different fishing mortalities are calculated in line with the stock annex using updated parameters for mean weight and proportions of removals retained (ICES, 2013) and are given in Table 8. This implies total catches fishing at F_{msy} ($=F_{35\%spr}$) in 2014 of 699 tonnes which results in landings of no more than 591 tonnes, where total catches are the landings, plus dead and surviving discards.

Discussion

Observed burrow densities have fluctuated a lot over time in this area. This is in contrast to the rather stable burrow abundance estimates in FU15 and FU22 over similar time frames (Lordan et al 2012 and Doyle et al. 2012). The burrow abundance decreased significantly in 2012 and the 2013 survey estimate is not significantly different (although it is the lowest in the 12 year time series). No lower abundance limit (i.e. MSY $B_{trigger}$) has been defined by ICES for FU17 mainly due to the relative shortness of the time series. There is no real objective way of setting a MSY $B_{trigger}$ from UWTV surveys other than using a lowest observed abundance when a suitably long time series exists. In the last two years the large reduction in burrow abundance was very striking across the whole ground. It was particularly obvious in the northern parts of the ground where the once heavily bioturbated sea bed was very flat and featureless.

The fishing mortality in 2012 was well above the target (F_{msy}). Despite the decline in abundance fishing effort and landings in 2012 and first half of 2013 have remained stable at a high level and the industry reported high catch rates of unusually high quality (i.e. large) *Nephrops*. Landings per unit effort (Lpues) in 2012 were the highest ever observed (ICES, 2013). The fact that the survey abundance in this area tends to fluctuate more than and is not well correlated with LPUEs has been highlighted in previous survey reports. Last year's survey report speculated that the explanation for high variability in abundance could be linked to the survey observing variable recruitment or that natural mortality may be high and/or variable on this ground. The low abundance in 2012 and 2013 cannot be linked to causative factors as yet. Discard rates were a little lower in 2012 but the mean size data on the survey or in the fishery doesn't suggest weak recruitment or other problems in the stock.

The landings from this area have generally fluctuated between 600-1,000 t since 1995. The landings advice for 2014 of 591 t represents a significant reduction on the 2012 landings of ~1,100 t and is towards the lower end of what has been observed from the developed fishery (i.e. since the mid-1990s).

There are a number of relatively recent improvements in the information base that will need to be incorporated when this stock is next benchmarked. The multi-beam boundary mapping work (Figure 1), the developing time series of VMS data and UWTV observations will undoubtedly improve the boundary definition for the main Aran ground area. This is expected to scale up the abundance for the Aran ground by at least 10% in most years. These raised burrow abundance estimates for Galway Bay and Slyne Head should also be included. For the moment these underestimates in stock abundance are taken into account within the bias correction factor applied for the whole of FU17 advice. This new information will require a revision of this bias correction factor but the relative contribution to landings from the different patches within FU17 should also be investigated.

The collection of length-weight and maturity data are required under the Data Collection Framework (DCF). The sampling data, including on this survey, should be investigated at or before the next benchmark to see if length-weight or maturity parameters require revision. In contrast to last year the 2013 length-weight parameters for females were not significantly different from those used currently (ICES, 2013).

Macrobenthos data from the trawl catches was collected for the fourth year. The dominant species by weight was *Nephrops norvegicus* followed by *Lunatia species* (necklace shell) and then *Crangon* species (brown shrimp). Overall there is a similar benthic species composition between the tows reflecting the habitat type encountered which is generally sandy mud. *Virgularia mirabilis* were caught by the beam trawl and recorded in all 7 tows and this reflects the common occurrence of this species observed on the video footage.

Two other burrowing species: *Goneplax rhomboids* (box crab) and *Munida rugosa* (squat lobster) were recorded. Of those *Goneplax rhomboids* was the most abundant. The burrows of these species can lead to confusion with *Nephrops* burrows in areas of soft mud and high burrow densities. However, such allocation errors are minimised due to the training procedures employed during the survey. These include refresher training on classical *Nephrops* burrow signatures and consistency verification with reference count analyses (ICES 2008 & 2009b).

A broad diversity of fish species were caught (25 species). Of these *Glyptocephalus cynoglossus* (witch) was the most abundant followed by *Merlangius_merlangus* (whiting). These species are typically encountered in the catches of surveys and commercial vessels on the Aran grounds.

An important objective of this UWTV survey is to collect various ancillary information. The occurrence of trawl marks on the footage is notable for two reasons. Firstly, it makes identification of *Nephrops* burrows more difficult as the trawl marks remove some signature features making accurate burrow identification more difficult. Secondly, only occupied *Nephrops* burrows will persist in heavily trawled grounds and it is assumed that each burrow is occupied by one individual *Nephrops* (ICES 2009b). The CTD data collected will be processed at a later stage. This information is relatively easy to collect and over time will augment the knowledge base on habitat and oceanographic regime.

The main objectives of the survey were successfully met for the twelfth successive year. The UWTV coverage and footage quality was excellent throughout the survey. Also the number of beam trawls was limited to 7 out of a planned 10. The multi-disciplinary nature of the survey means that the information collected is highly relevant for a number of research and advisory applications.

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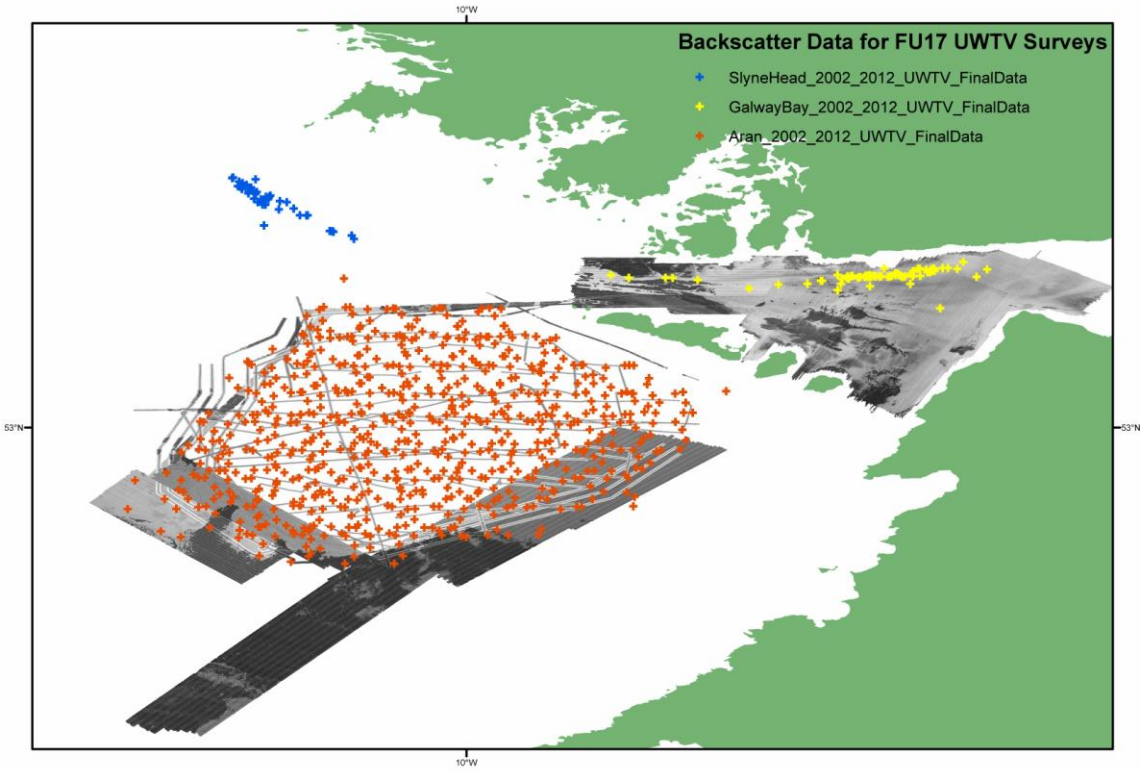

Figure 1: The spatial distribution of all UWTV survey stations between 2002-2012 in Functional Unit 17 overlaid on multibeam backscatter data (source: INFOMAR). Darker backscatter indicates harder seabed substrate.

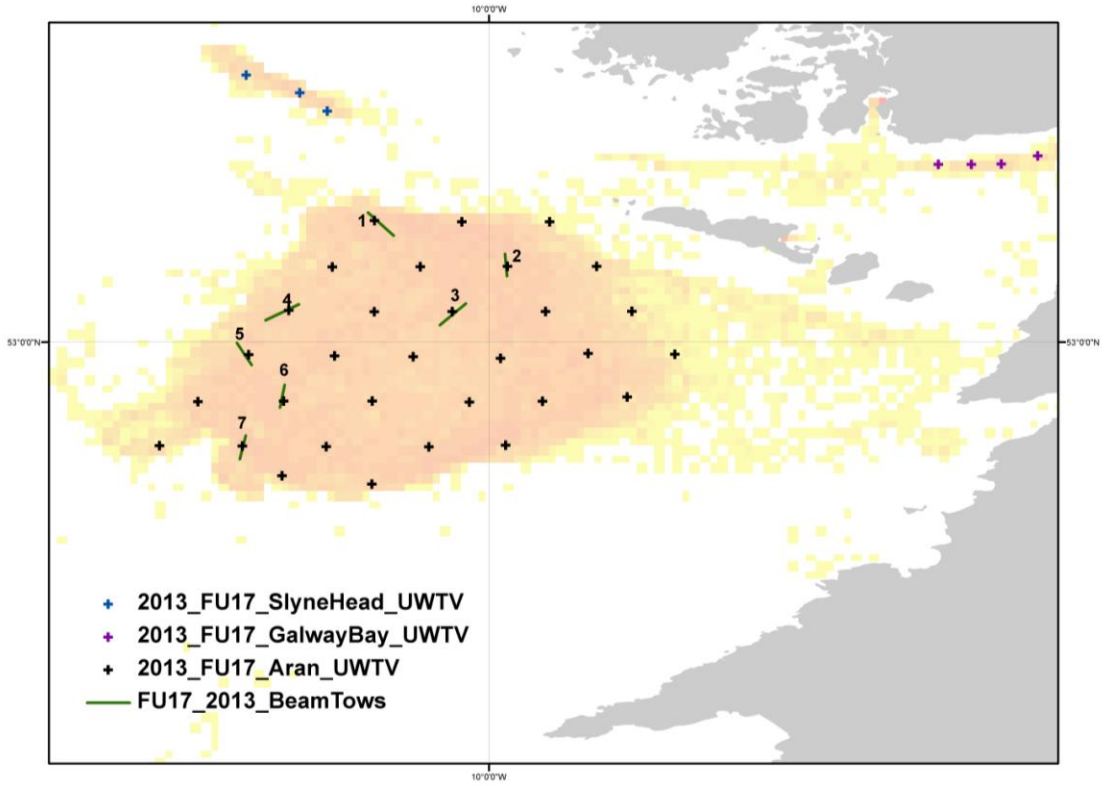

Figure 2: FU17 Aran grounds: UWTV Stations and beam trawl tacks completed in 2013 overlaid on a heat map *Nephrops* directed fishing activity between 2006-2012.

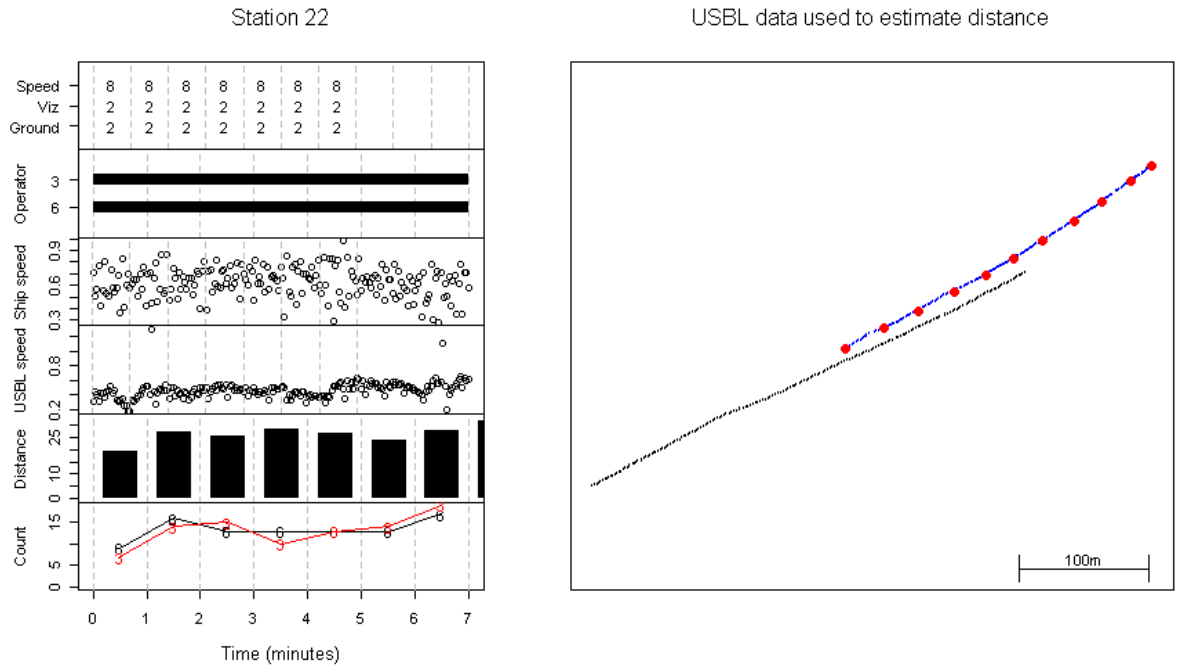

Figure 3 : FU17 Aran grounds: r - tool quality control plot of station 22 of the 2013 survey.

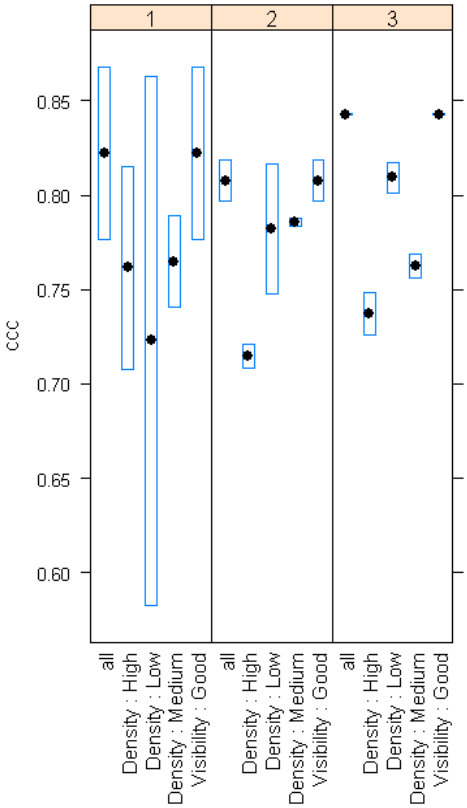

Figure 4: FU17 Aran grounds: 2013 Counting performance against the reference counts as measured by Linn's CCC for FU17 "Aran grounds". Each panel represents an individual. The x-axis (from left to right), all stations pooled, high density, low density, medium density and visibility good.

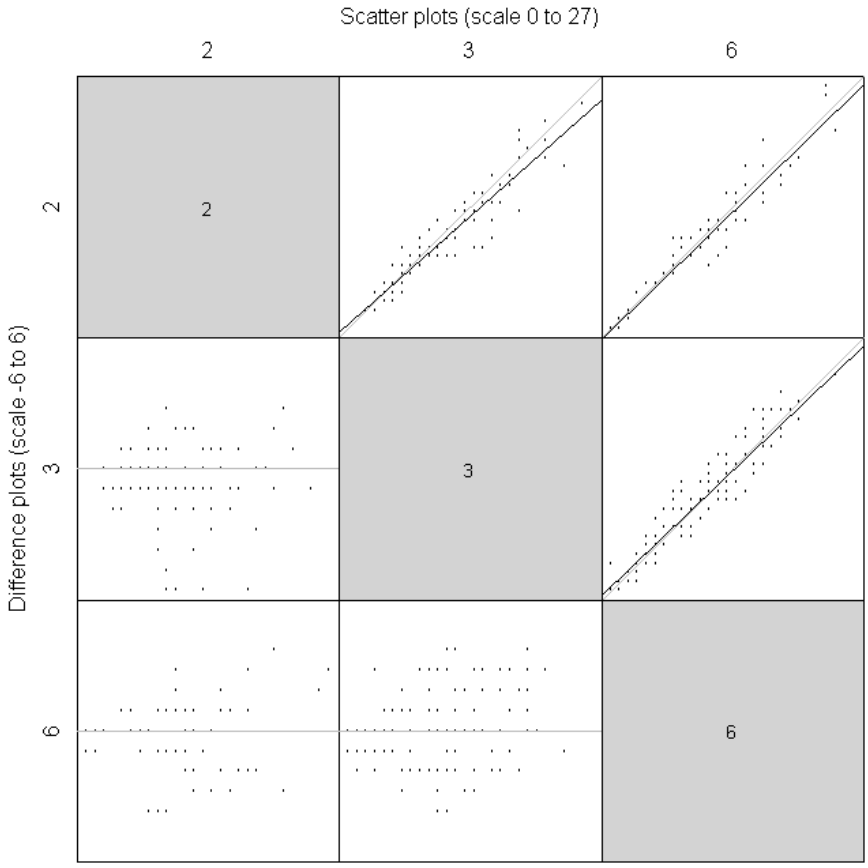

Figure 5: FU17 Aran grounds: Scatter plot analysis of counter correlations for the 2013 survey.

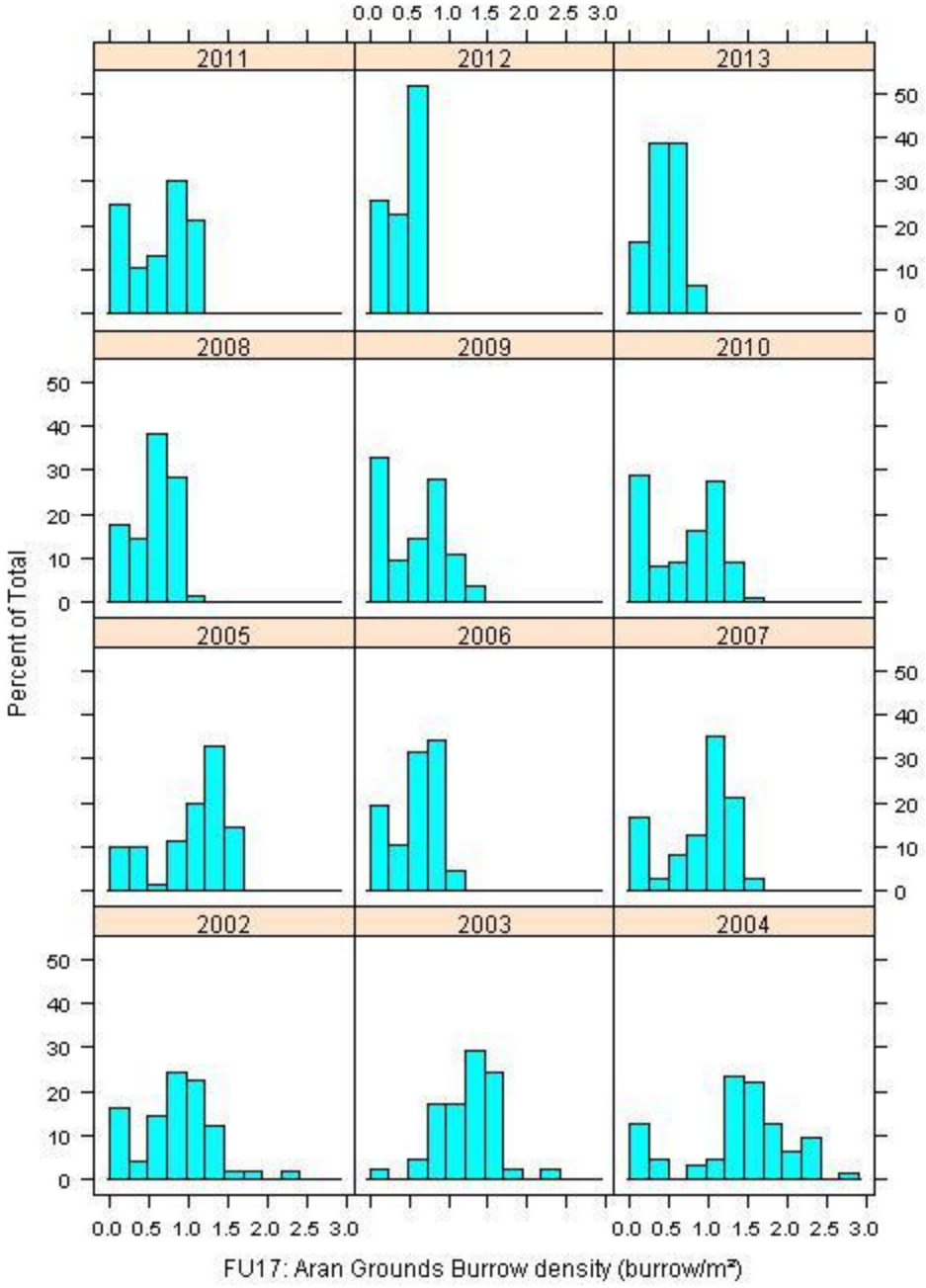

Figure 6: FU17 Aran grounds: Histograms of observed burrow density distributions by year from 2002-2013.

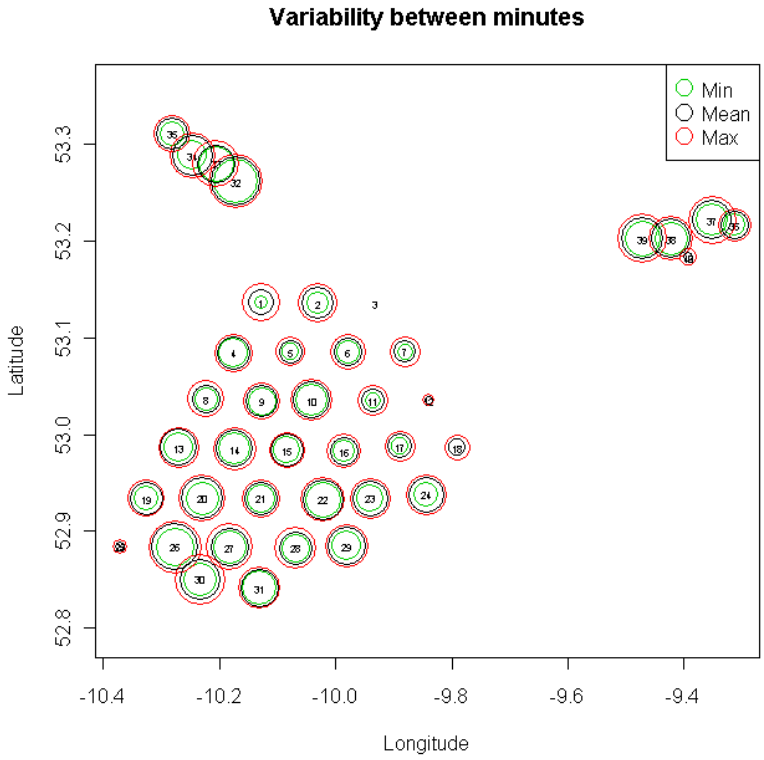

Figure 7: FU17 Aran grounds: Plot of the variability in density between minutes for each station in 2013.

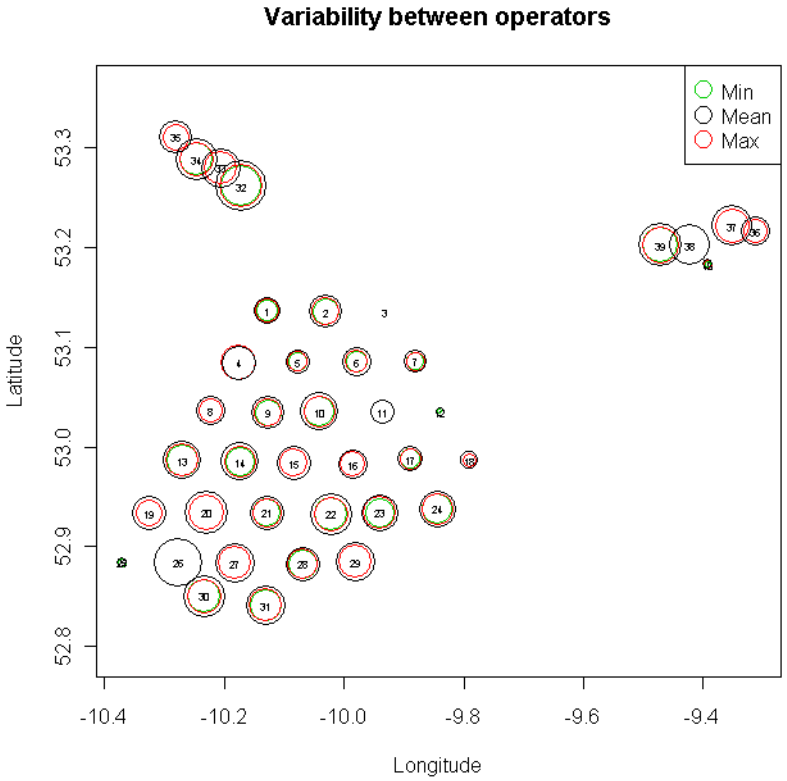

Figure 8: FU17 Aran grounds: Plot of the variability in density between operators (counters) for each station in 2013.

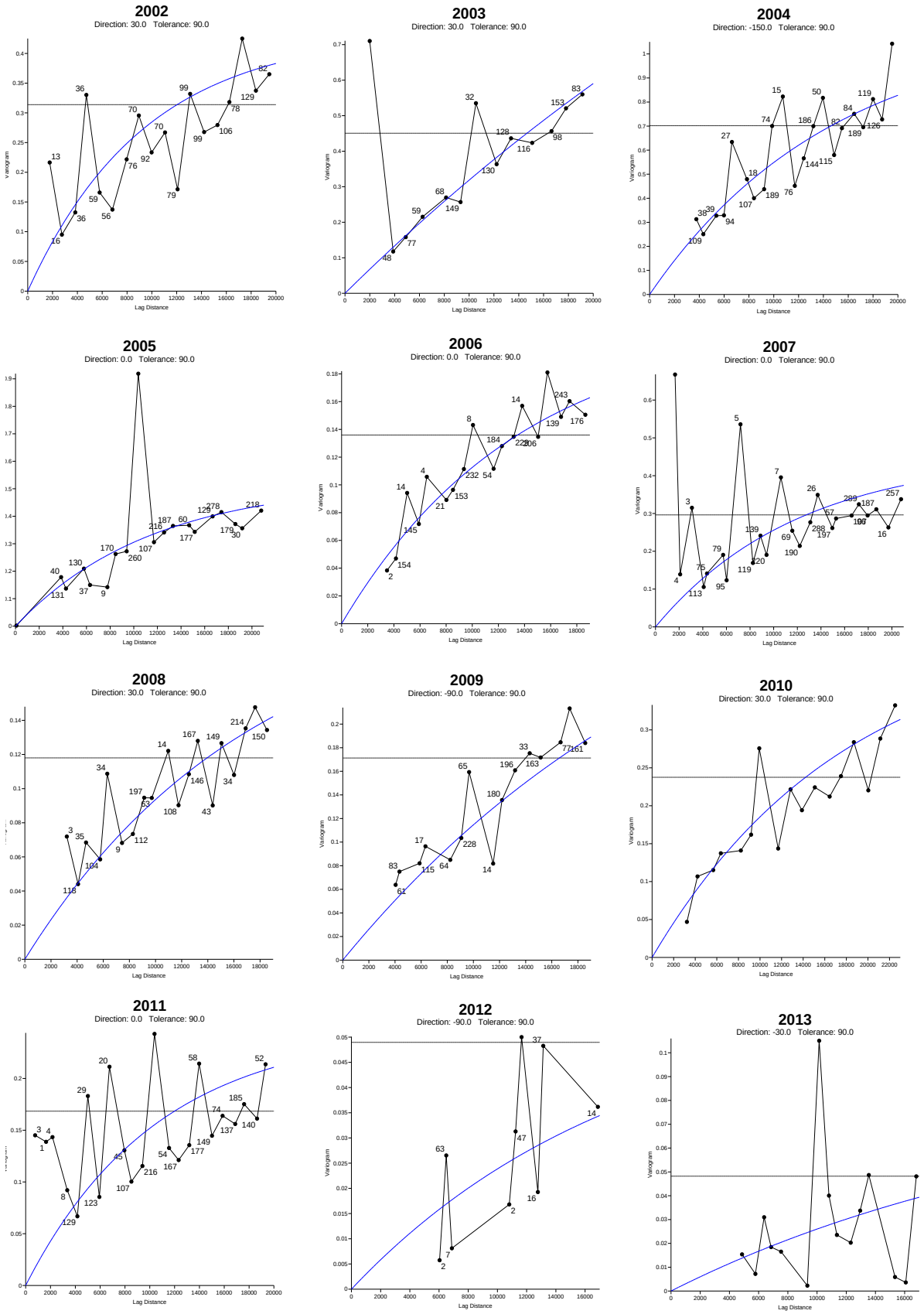

Figure 9: FU17 Aran grounds: Omnidirectional mean variograms by year from 2002-2013.

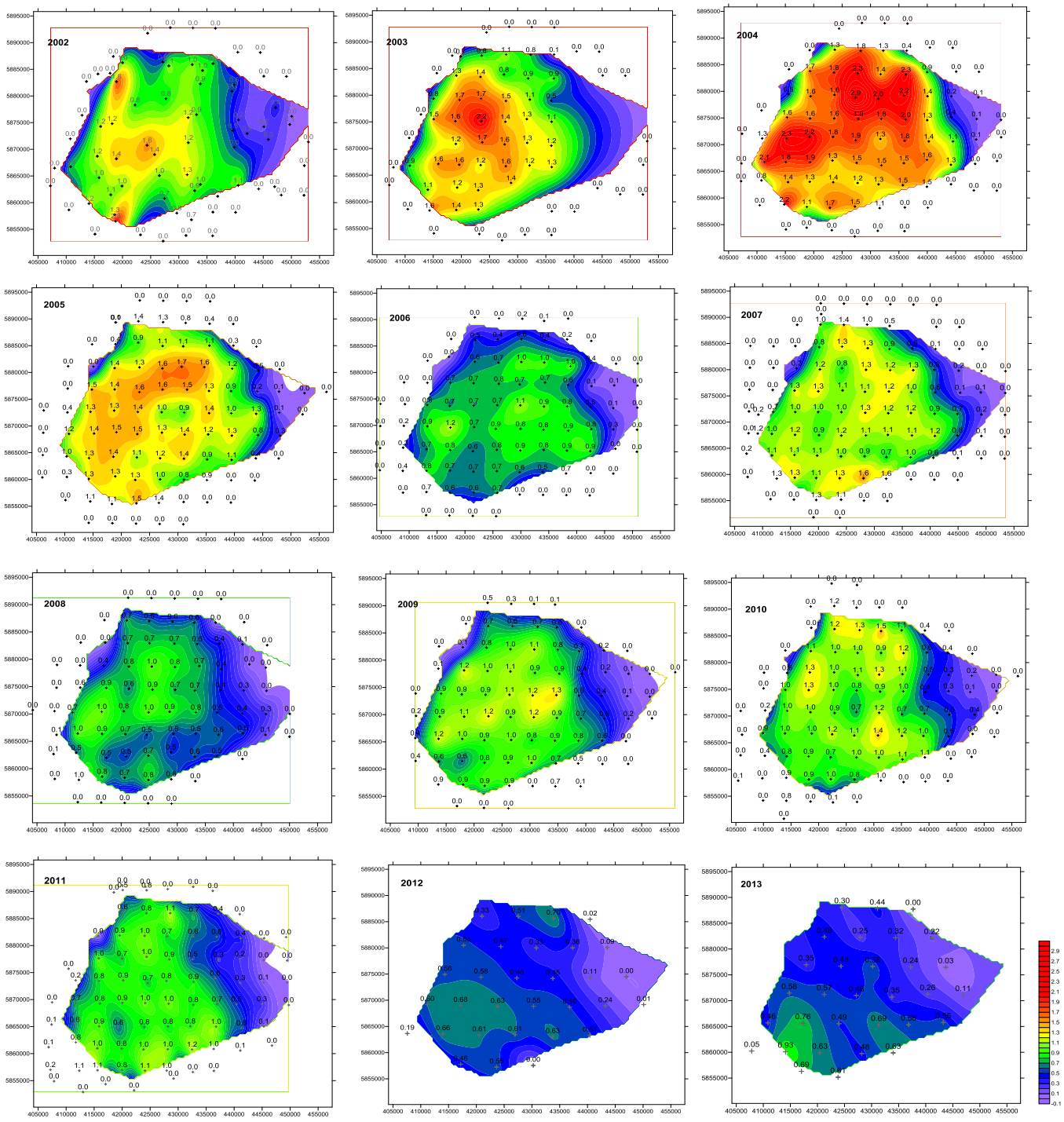

Figure 10: FU17 Aran grounds: Contour plots of the krigged density estimates by year from 2002 (top left) - 2013 (bottom right).

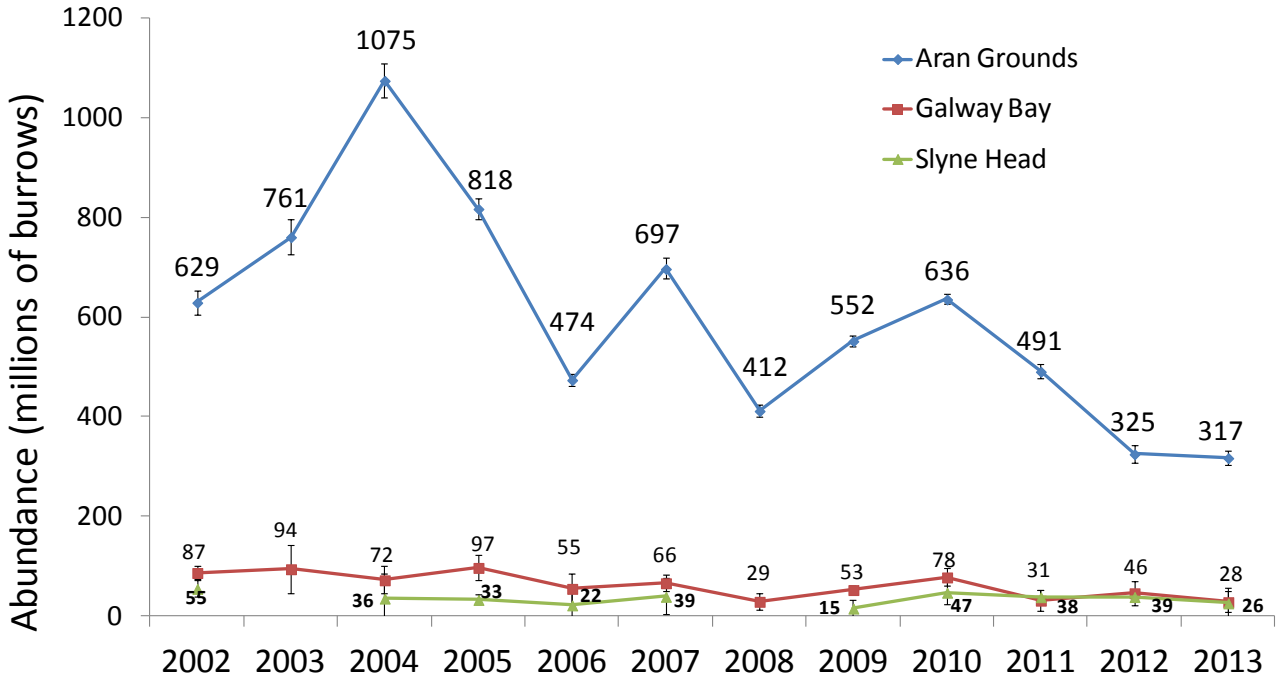

Figure 11: FU17 Aran grounds: Time series of geo-statistical adjusted abundance estimates for the Aran Grounds and raised adjusted estimates for Galway Bay and Slyne Head 2002-2013 (error bars indicate 95% confidence intervals).

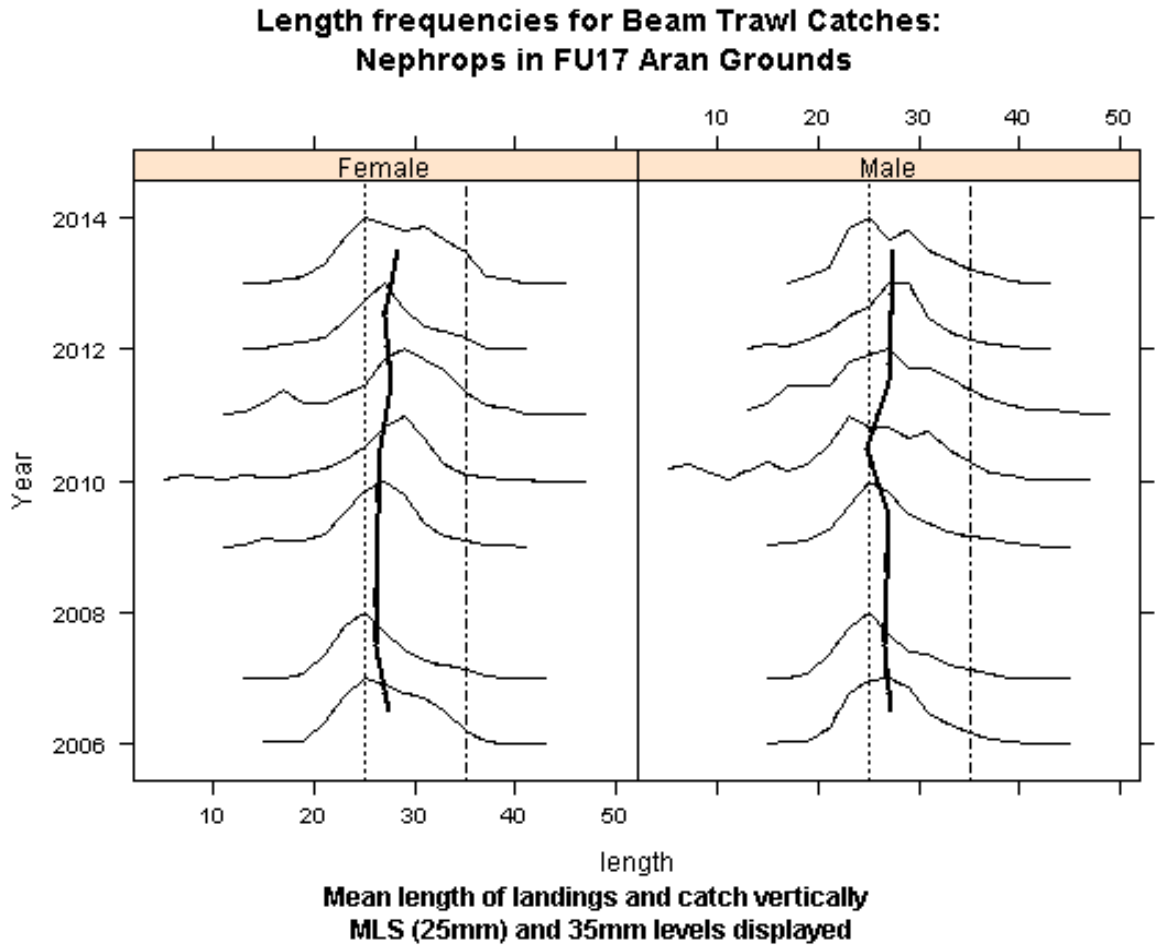

Figure 12: FU17 Aran grounds: Standardised length frequency distributions for male and female *Nephrops* caught using beam trawl during 2006 to 2013 UWTV surveys on the "Aran Grounds" (except 2008).

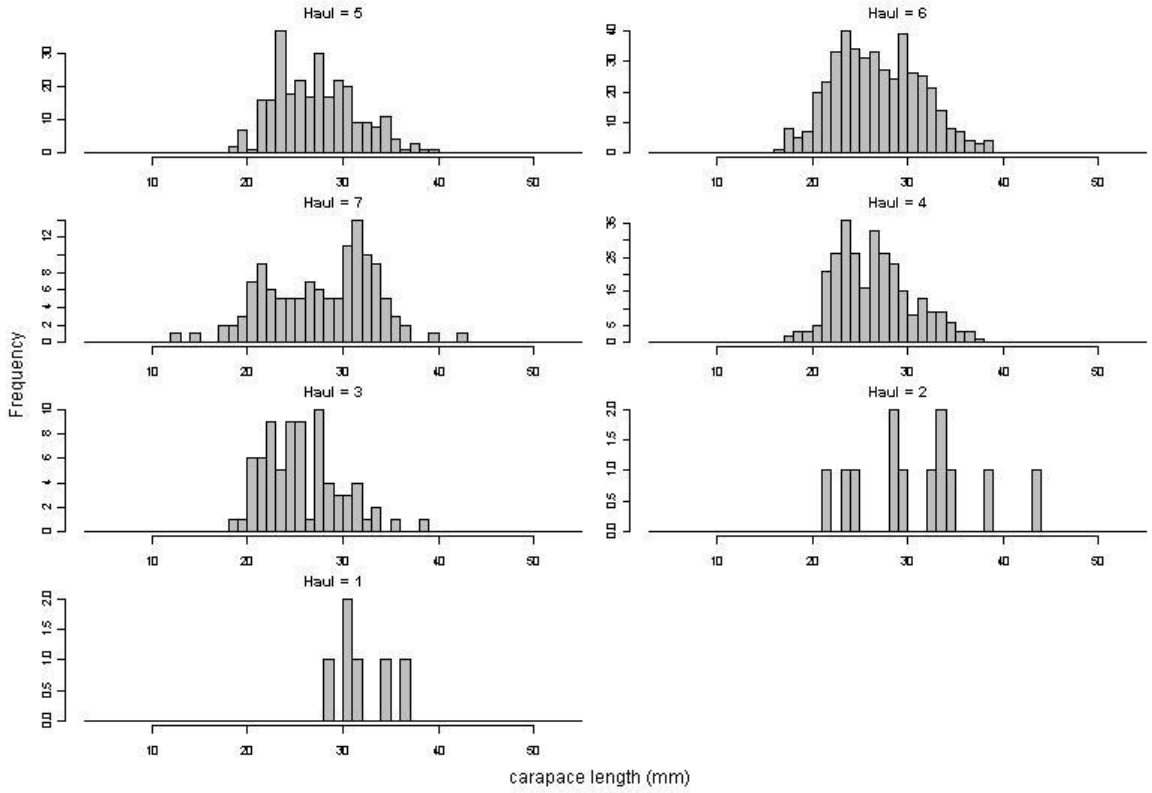

Figure 13: FU17 Aran grounds: 2013 *Nephrops* length frequencies by haul.

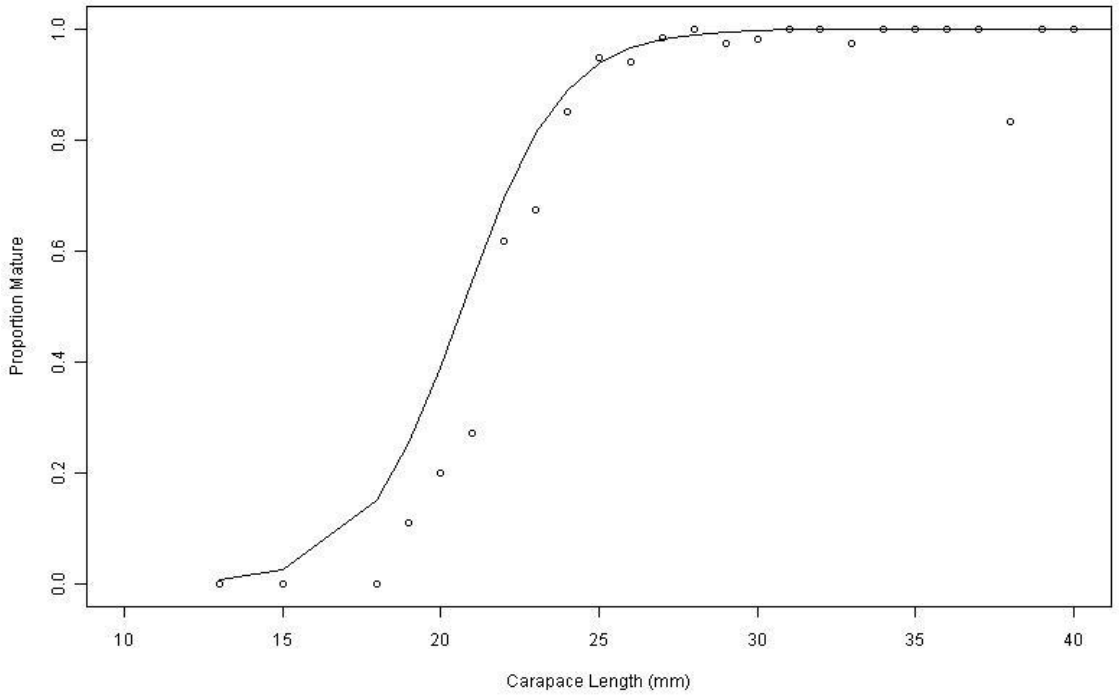

Figure 14: FU17 Aran grounds: Female *Nephrops* maturity ogive based on beam trawl catches in 2013 (L_{50} estimate ~ 23 mm).

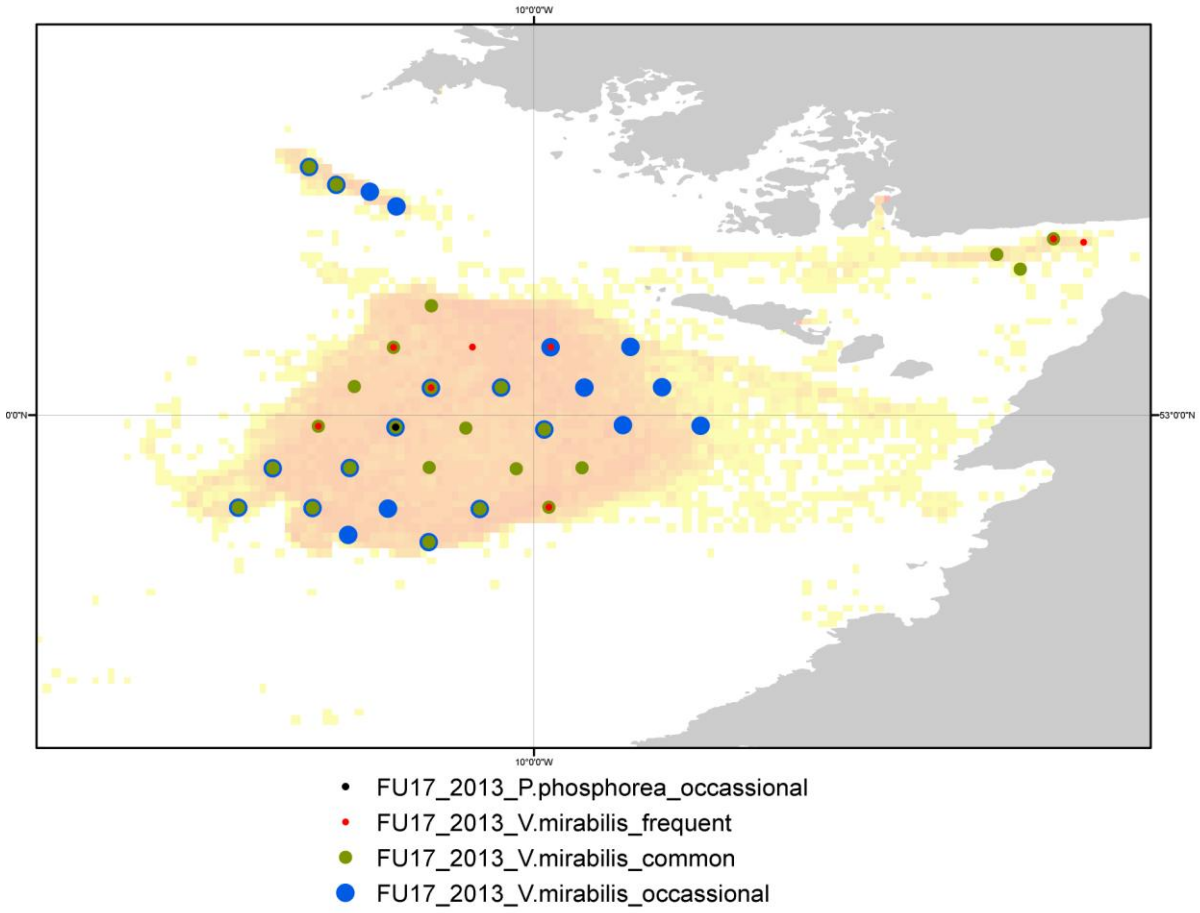

Figure 15: FU17 Aran grounds: Stations where *Virgilaria mirabilis* and *Pennatula phosphorea* were identified during 2013 overlaid on a heat map *Nephrops* directed fishing activity.

Table 1: Key for classification of Seapen abundance as used on Irish UWTV surveys.

	Number/Min
Common	20-200
Frequent	2-19
Ocasional	<2

Species
Virgularia mirabilis
Pennatula phosphorea
Funiculina quadrangularis

Sea Pens								
V. mirabilis			*P. phosphorea*			*F. quadrangularis*		
C	F	O	C	F	O	C	F	O

Table 2: FU17 Aran grounds: Area calculations for Galway Bay and Slyne Head *Nephrops* grounds in ArcGIS10.

		ArcGIS Projections			
FU	VMS grounds Polygons	Eckert VI (world) (km2)	Irish National Grid (km2)	Cylindrical Equal Area (km2)	Average (km2)
17	SlyneHead	39.3	39.4	39.3	39.3
17	GalwayBay	74.2	74.0	74.0	74.1

Table 3: FU17 Aran grounds: Overview Aran of geostatistical results from 2002-2013.

FU	Ground	Year	Number of stations	Burrow Count	Mean Density adjusted (burrows/m²)	Estimation Standard Deviation	Domain Area (km²)	Geostatistical abundance estimate adjusted (millions of Burrows)	CV on Burrow estimate
17	Aran	2002	49	7,036	0.65	0.04	943	629	4%
		2003	41	9,814	0.78	0.06	943	761	5%
		2004	64	10,687	1.10	0.05	943	1075	3%
		2005	70	8,774	0.84	0.03	936	818	3%
		2006	67	6,928	0.49	0.02	932	474	3%
		2007	71	10,272	0.71	0.03	942	697	3%
		2008	63	7,617	0.43	0.02	906	412	3%
		2009	82	6,585	0.56	0.02	940	552	2%
		2010	91	8,091	0.65	0.01	937	636	2%
		2011	76	7,365	0.51	0.02	909	491	3%
		2012	31*	1,271	0.34	0.02	942	325	5%
		2013	31*	1,937	0.32	0.00	941	317	4%

* reduced isometric grid 3.5nmi

Table 4: FU17 Aran grounds: Summary statistics for the Galway Bay and Slyne Head *Nephrops* grounds from 2002-2013.

FU	Ground	Year	Number of stations	Area Surveyed (km²)	Burrow count	Mean Density adjusted (burrow/m²)	95%CI	CViid (Relative SE)	Raised abundance estimate adjusted (million burrows)
	Galway Bay	2002	7	1.249	1,905	1.17	0.17	5.9%	86.9
		2003	3	0.568	941	1.29	0.66	11.9%	94.5
		2004	9	1.099	1,394	1.02	0.37	15.7%	72.3
		2005	4	0.443	755	1.30	0.34	8.2%	97.2
		2006	3	0.540	522	0.74	0.40	12.5%	55.1
		2007	5	0.852	992	0.91	0.22	8.6%	66.4
		2008	9	1.669	852	0.35	0.22	21.4%	29.1
		2009	8	1.207	1,116	0.71	0.11	6.2%	52.7
		2010	10	1.284	1,757	1.24	0.24	8.6%	78.0
		2011	10	1.353	745	0.39	0.29	32.8%	31.4
		2012	4	0.460	374	0.64	0.33	16.1%	46.3
		2013	5	0.826	412	0.37	0.28	27.3%	28.4
	Slyne Head	2002	5	1.054	1,019	0.75	0.23	11.3%	55.1
		2003	-	-	-	-	-		
		2004	3	0.505	315	0.51	0.66	29.9%	35.5
		2005	3	0.338	195	0.44	0.13	7.0%	32.9
		2006	3	0.546	210	0.30	0.49	37.8%	21.9
		2007	4	0.796	547	0.51	0.49	30.6%	39.1
		2008	-	-	-	-	-		
		2009	6	0.531	144	0.31	0.23	29.2%	15.5
		2010	9	1.117	928	0.57	0.33	25.4%	47.3
		2011	7	1.166	785	0.51	0.17	13.7%	38.3
		2012	3	0.405	275	0.52	0.09	4.1%	38.7
FU17		2013	4	0.609	277	0.54	0.42	24.7%	25.9

* revised 2002 - 2008 for Galway Bay and Slyne Head

Table 5. FU17 Aran grounds: Length-weight parameters by sex estimated for *Nephrops* caught during the 2013 survey together with those currently used to raise the sampling data.

FU	Year	Parameters	Female	Male
		a currently used for FU17	0.000684	0.000322
		b currently used for FU17	2.963	3.207
		a estimated		
		a 2.5% Confidence Intervals	-7.749241	-8.50328
		a 97.5% Confidence Interval	-7.192772	-7.924117
		b estimated	3.02586	3.266926
		b 2.5% Confidence Intervals	2.944124	3.179625
		b 97.5% Confidence Interval	3.107602	3.354227
		Bias Correction Factor	1.003259	1.004529291
17	2013	Number of Observations	119	148

Table 6: FU17 Aran grounds: Summary of benthic catch by tow in weight (kg) and number from 2013 fishing operations.

	Tow1		Tow2		Tow3		Tow4		Tow5		Tow6		Tow7	
Species	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number
Actinuage richardii							0.006	1			0.067	1		
Alyconium glomeratum									0.004	1				
Alpheus gaber											0.002	1		
Anemone (Dahlia)			0.004	1										
Aphrodite aculeata			0.228	3	0.046	1	0.106	1	0.046	1				
Armeni loveni	0.002	1			0.006	5							0.002	1
Asterias rubens									0.004	1				
Astropecten irregularis			0.014	2			0.006	1	0.004	1				
Carcinus maenus	0.027	1	0.039	2										
Corystes cassivelaunus			0.002	2										
Crangon spp	0.216	91	0.306	300	0.095	93	0.446	420	0.134	123	0.252	245	0.293	164
Dichelopandulus bonneri							0.001	2	0.004	2	0.002	1		
Eledone cirrhosa	**0.252**	**3**					**0.466**	**3**	**0.161**	**3**	**0.134**	**1**	**0.132**	**1**
Goneplax rhomboides	**0.006**	**1**	**0.011**	**3**	**0.004**	**1**	**0.003**	**1**	**0.017**	**1**	**0.010**	**1**	**0.032**	**6**
Jellyfish spp	0.152	1	0.330		0.169		0.104		0.284		0.027		0.016	
Liocarcinus depurator			0.098	19	0.001	1	0.033	6	0.002	1	0.046	9	0.009	1
Liocarcinus holsatus	0.007	4	0.003	6	0.003	1	0.002	1						
Lophogaster typicus					0.001	3	0.001	3						
Luidia spp	0.025	1												
Lunatia spp	0.147	17	0.466	210	0.019	8	0.626	265	0.372	149	0.170	90	0.234	136
Munida rugosa					**0.001**	**1**								
Nephrops norvegicus	**0.137**	**6**	**0.424**	**12**	**0.904**	**76**	**3.748**	**287**	**4.076**	**272**	**6.342**	**437**	**2.050**	**125**
Nucula nucleus			0.001	1			0.004	6	0.004	4	0.001	1		
Pagurus spp			0.006	1			0.053	13	0.013	2	0.012	2	0.010	2
Pasiphaea sivado							0.003	1						
Pontophilus spinosa	0.131	13	0.018	22	0.014	15	0.021	22	0.062	8	0.003	4	0.013	13
Processa spp			0.002	1			0.002	2	0.002	3	0.082	58	0.243	78
Scapellum scapellum							0.004	1	0.004	1	0.008	4		
Isopoda spp													0.002	2
Seaweed spp	0.050		0.310		0.098		0.007		0.006		0.002		0.018	
Sepiola spp (Atlantica)	0.121	1	0.007	5	0.008	4	0.128	5	0.005	3	0.002	1		
Solenocera membranosa											0.011	3	0.030	16
Stichastrella rosea			0.002	1			0.014	3	0.011	3			0.006	3
Tealia feline							0.005	1						
Virgilaria mirabilis	**0.006**	**3**	**0.003**	**8**	**0.003**	**15**	**0.006**	**26**	**0.003**	**25**	**0.003**	**10**	**0.002**	**4**
Worm casings			0.001	1			0.002	1	0.000	1				
Total	1.279	143	2.274	600	1.369	224	5.797	1072	5.219	605	7.174	869	3.089	552

Table 7: FU17 Aran grounds: Summary of fish catch by tow in weight (kg) from 2013 fishing operations.

Species	Weight (kg)						
	Tow1	**Tow2**	**Tow3**	**Tow4**	**Tow5**	**Tow6**	**Tow7**
AMMODYTES SPP			0.022				
ARGENTINA SPHYRAENA					0.008		
ARNOGLOSSUS LATERNA	0.036	0.018					
ASPITRIGLA (CHELIDONICHTHYS) CUCULUS							0.019
CALLIONYMUS LYRA	0.008	0.061	0.152	0.122	0.070	0.026	0.160
CAPROS APER	0.002						
DIPTURUS INTERMEDIA		0.074				0.156	
EUTRIGLA (CHELIDONICTHYS) GURNARDUS	0.118	0.064	0.188	0.072	0.040		0.372
GADICULUS ARGENTEUS							0.125
GAIDROPSARUS VULGARIS		0.012	0.010		0.172	0.030	0.139
GLYPTOCEPHALUS CYNOGLOSSUS	0.008	0.504	0.410	0.530	0.570	0.340	0.632
GOBIES	0.002		0.004				
HIPPOGLOSSOIDES PLATESSOIDES	0.113	0.254	0.136	0.244	0.272	0.292	0.267
LEPIDORHOMBUS WHIFFIAGONIS	0.416			0.138	1.064	0.446	
LOPHIUS BUDEGASSA					0.028		
LOPHIUS PISCATORIUS	0.252	0.496			0.212		0.366
MELANOGRAMMUS AEGLEFINUS	0.003	0.012	0.004				0.132
MERLANGIUS MERLANGUS	0.024	0.095	0.016	0.326	0.002	1.298	0.406
MERLUCCIUS MERLUCCIUS	0.688	0.288	0.096	0.266		0.040	0.199
MICROCHIRUS VARIEGATUS				0.028	0.042		
MICROSTOMUS KITT	0.156						
SCYLIORHINUS CANICULA		0.022					
SOLEA SOLEA				0.096			0.426
Transparent eel-like ribbon fish							0.128
TRISOPTERUS ESMARKI					0.124	0.114	0.209
Total Weight (kg)	1.826	1.900	1.038	1.822	2.604	2.742	3.580

Table 8: FU17 Aran grounds: Short-term forecast management option table giving total catch and landings options for 2014 using the 2013 UWTV survey estimate.

Basis	Total catches*	Landings	Dead discards**	Surviving discards**	Harvest rate
	L+DD+SD	L	DD	SD	for L+DD
F_{MSY} proxy	669	591	70	8	10.5%
F_{2013}	1223	1080	129	14	19.2%
$F_{0.1\ Combined}$	459	405	48	5	7.2%
F_{max}	707	625	74	8	11.1%

Weights in tonnes.

* Total catches are the landings, plus dead and surviving discards.

** Total discard rate is assumed to be 18.8% of the catches (in number, average of the last three years, 2010–2012); discard survival is assumed to be 10%.